BIM METHODOLOGY FOR THE OPTIMIZATION OF EDUCATION SECTOR PROJECTS IN AN URBAN ENVIRONMENT AT THE DESIGN STAGE

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ABSTRACT

The study describes the advantages of the Building Infomation Modeling (BIM) methodology, comparing it with the traditional processes used today. It was based on the professional experience acquired in the development of the projects of the education sector in an urban environment in the A.B.C Arquitecto-Ingenieros S.R.L company, where both approaches in the design stage allowed demonstrate and fulfill the main objective that BIM develops efficiency in education sector projects; and that efficiency is translated in that: a) the BIM methodology optimizes the timeframes in the elaboration of plans by 64%, b) optimizes the detection and resolution of interferences by 88% and 112% and c) optimizes the yields in the elaboration of metrics by 70%; the improvement was calculated thanks to the data collection of tasks of the same nature of both processes within the company in a face-to-face and virtual way. In addition, this paper describes how the traditional process causes several difficulties in developing a project in the design stage, limiting the workflow due to the lack of coordination; likewise, this paper contains information on the current regulations.

CHAPTER I. INTRODUCTION

1.1.General Context

The construction industry plays a fundamental role in each country's economy, generates employment, drives various input supplier industries, etc. As Platt (2017) mentioned, this industry represents a fundamental pillar in the economy and urban development. However, the execution of a construction project brings in many opportunities and significant obstacles to its completion, such as low productivity index, cost overruns, deadline extensions, and several waste, etc. These obstacles translate into an increase between 5 to 25% of the total cost of the project, according to studies in North America, South America and the United Kingdom (Santelices *et al.*, 2019). In line with the authors, these drawbacks are generated by the lack of control in the early ages of the project, that is, in the design stage; in addition, they describe as the leading causes of the obstacles the lack of coordination, incompatibilities in plans between various specialties and low level of accuracy; noting that this is given by the use of inaccurate technology and/or craftsmanship, as these do not provide the required levels of detail. Therefore, in the end, it is not obtained correct or clear knowledge of how to plan the construction of the project and it is left to interpretation.

Over the years, the design stage of a construction project has been developed under traditional processes based on the sequence of work of the different specialists that make up the project. These generate independent products, ultimately producing several problems reflected in the construction stage. In other words, with the traditional process, there is a greater probability of making mistakes since coordination can be lost, ultimately affecting the project's cost, time and quality (Olives, 2021).

The alternative solution to the problem located in the design stage is the implementation of the Building Information Modeling (BIM) methodology. This methodology is not new in the world; however, its implementation in practice is feasible and more concrete today. It also promotes collaborative work, allowing better project management, and providing quality and efficiency (Fridrich *et al*., 2014).

In the process of developing a project under the BIM approach, it was concluded that what makes this methodology powerful and different from the conventional process is the parametric model. This model adds dynamism and flexibility to the work processes; consisting of modeling the construction elements of various specialties, these elements integrate all types of information, ranging from the geometric figure, type of material, time, and costs, among others, which, finally, all this information will be necessary for its execution.

The traditional process used in elaborating on a building project involves several problems. When not solved in the design stage, these problems are identified in the project's construction; and range from lack of details, incompatibilities of plans, and inaccurate metrics, to an inappropriate budget estimation.

In line with Narváez (2020), developing the design of building projects under the traditional approach involves working based on document management, generating information losses between the different stages. For example: when the construction of a project begins, the construction company, upon receiving the technical file, must make a review report, where all the documents that make up the project are reviewed, producing doubts in its interpretation since there are many factors to take into account; therefore its information is lost. Here is a gap to fill: the need to link the information, no matter the project's stage. This loss of information occurs using the computer-aided design system (CAD). Figure 12 represents the preliminary stages that make up a project, and the declines or losses of information that occur under the traditional process or model, methodology based on independent documents, presented in green color.

In addition, another problem that occurs under traditional processes is the lack of integral control between all the specialties in the design stage. This stage is where the active and integrated participation of all the specialists that contemplate the project is required; however, the participation is given, but independently, which finally generates products that are not intertwined with each other. This individualistic way of working limits the interaction between the various actors involved in the project's development. When making corrections or generating modifications, this will be harmed since they are independent products and result in an inaccurate, inefficient product, presenting multiple inconsistencies, which will be evident in the construction phase.

Finally, the construction industry has failed to incorporate the technological advances that are developed today, which is why the need to stimulate the industry with alternative solutions that come from technology, to seek to compensate or eliminate the shortcomings of the traditional processes used by the conception of the project or design stage (Cabrera, 2019).

General problem

According to the described complex reality, the following has been formulated: How does the BIM methodology develop efficiency in education sector projects in an urban environment in the design stage, Lima 2021?

General Objective

Describe how BIM methodology develops efficiency in education sector projects in an urban environment in the design stage, Lima 2021.

DEVELOPMENT OF THE BIM METHODOLOGY

The process of detection and resolution of interferences that was developed will be described; all this in order to describe and demonstrate that the BIM methodology makes a big difference and advantage in this process. This activity was performed using the traditional process and BIM, the latter using Autodesk Revit and Naviswork software. By performing under these two approaches, it was possible to determine the quantitative benefit expressed in performance optimization and the more significant number of interferences detected with BIM vs. the traditional process, which will be detailed in the results chapter. Next, the sequential steps taken into account to detect and resolve interferences will be described.

3.1.1. Under the BIM approach

The detection of incompatibilities under the BIM methodology in project 1 was performed using the Naviswork 2019 software, which was fed from the digital models of each specialty: structures, architecture, sanitary inst.sanitary and inst.electrical. Under BIM, the steps to determine the number of incompatibilities are very efficient and practical, which translates into a significant advantage in time and accuracy, as it saves many person-hours in verifying inconsistencies. This is because the identification process is automatic, thanks to a programming tool that will be explained later. The sequence of incompatibility detection is described below.

- The modeling information of each specialty was required in Rvt format To determine a report of incompatibilities. These final models were hosted in the Naviswork program, a coordination-only program. As shown in Figure 1, the program hosts the total project, and opening the file takes reasonable time.

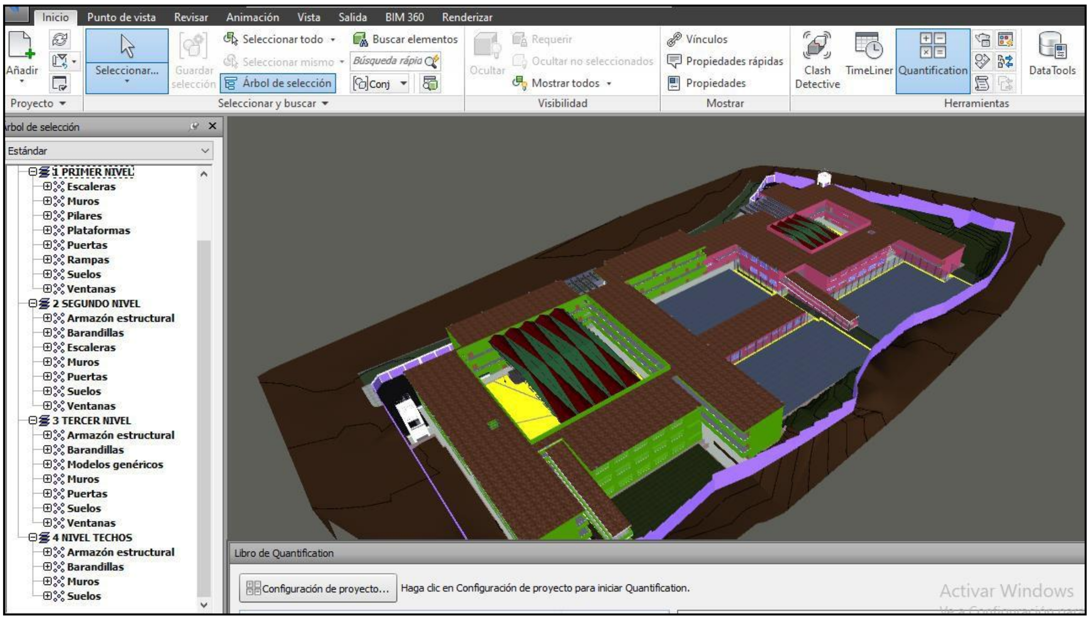


Figure 1. Integral project in Naviswork, of project 1

Source: A.B.C. Arquitectos Ingenieros S.R.L. company.

- Once all the specialties were integrated into the program, the authors proceeded to extract the information. This extraction of information was completed in two ways: visually and to verify with the generation of a report. The visual is through analysis, in this case of architecture with structure, through a tour is verified if there are gaps. For this, as shown in Figure 2, the architecture specialty was configured in yellow and the structure specialty in light blue; this was done by right-clicking on the layer of each specialty, option modify element and color. This revision was made block by block.

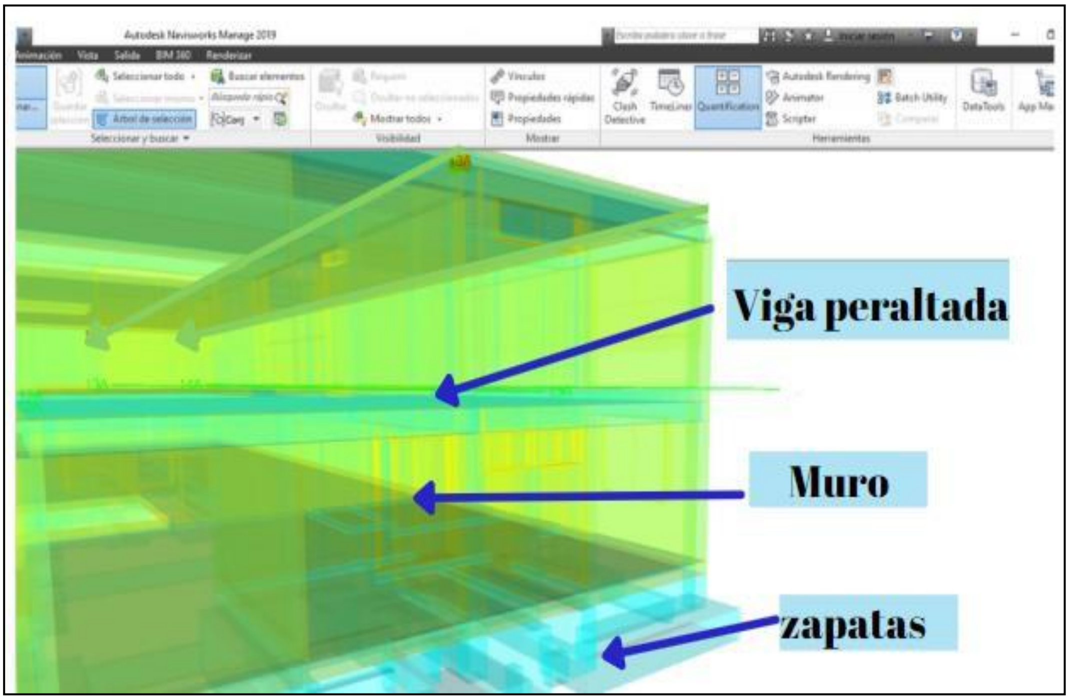


Figure 2. Visual tour in Naviswork Estr. and Arq, of project 1
Source: A.B.C. Arquitectos Ingenieros S.R.L. company.

- According to Figure 2, no mismatch or incompatibility was found in the visual tour of structures and architecture. This is because the modeling was done correctly. The same was done for the remaining specialties.

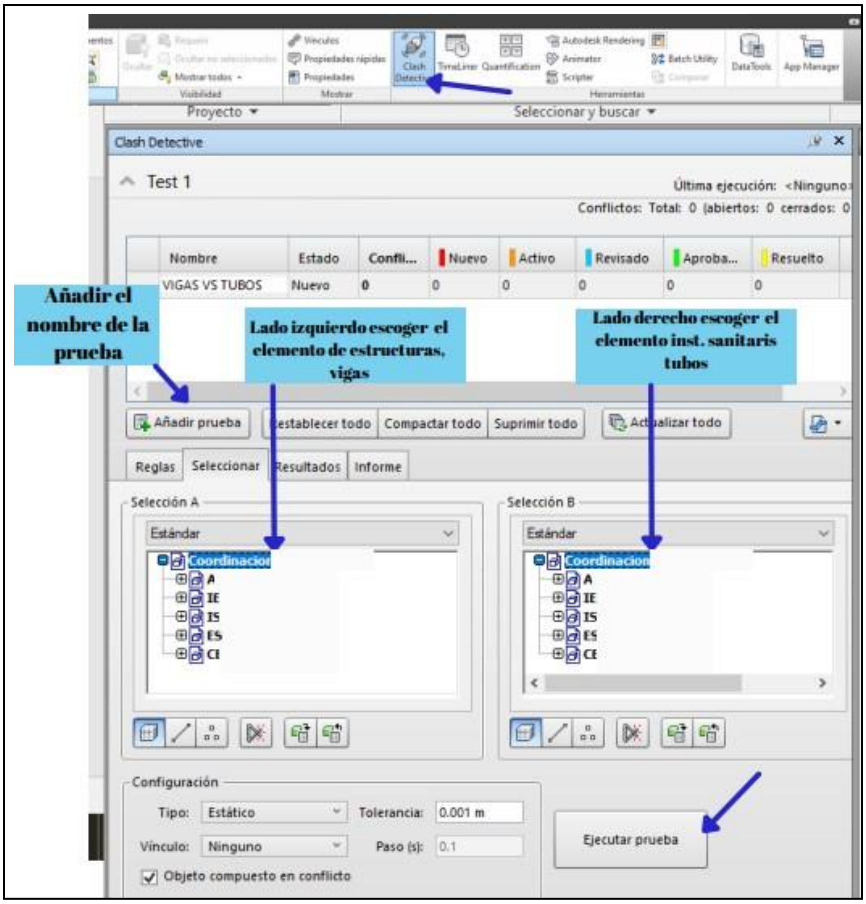
Figure 3. Visual tour in Naviswork Estr, Arq and Inst, of project 1

Source: A.B.C. Arquitectos Ingenieros S.R.L. company.

- However, reviewing visually will depend on the ability of the specialist to identify the intersection of elements, which can take several minutes since the entire project is navigated to identify any existing interference. In this project, for time management and to accurately identify the intersections, the authors used the "clash detective," located at the top of the program, which is an interference detector. This tool, through the generation of "tests," identifies some interference automatically and efficiently. For example, the following figure shows an interference test between beams vs. drainage pipes.

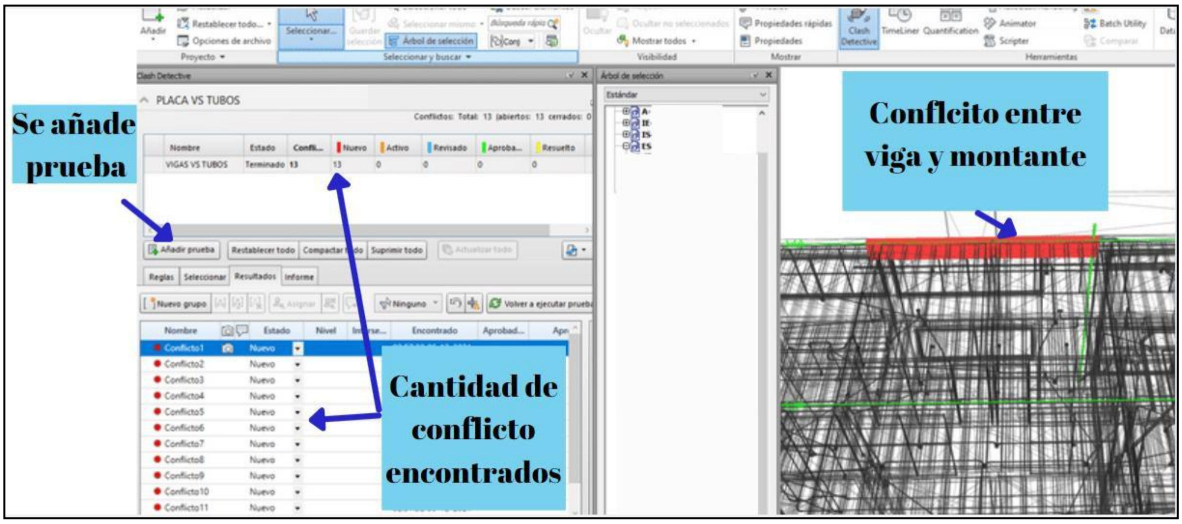
Figure 4. Sequence of test generation in Naviswork of project 1

Source: A.B.C. Arquitectos Ingenieros S.R.L. company.



- The test result yielded 13 detections, as shown in Figure 5.

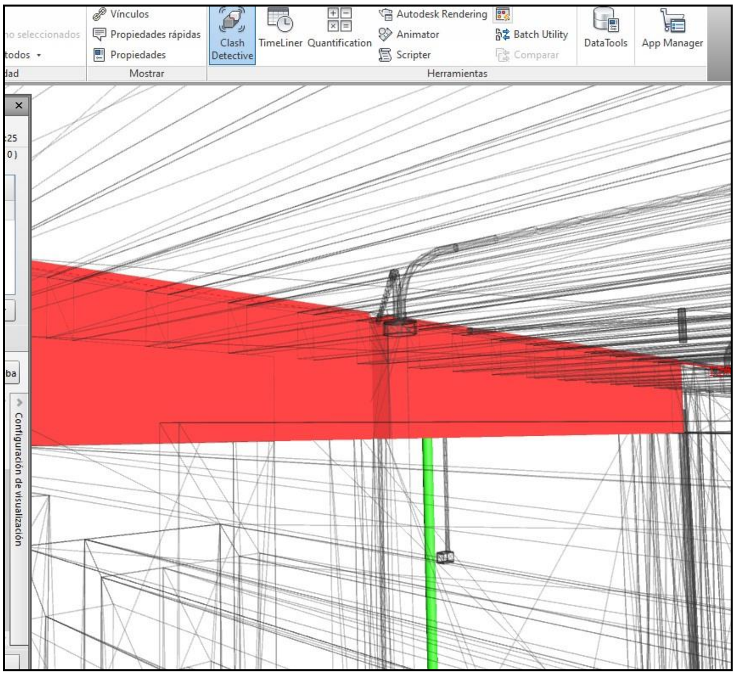
Figure 5. Result of interferences B-N°4 of project n°1



Source: A.B.C. Arquitectos Ingenieros S.R.L. company.

- As can be seen, the Naviswork program allows for making a precise and, above all, specialized revision.

Figure 6. Conflict number 5, B-N°4 of project 1



Source: A.B.C. Arquitectos Ingenieros S.R.L. company.

- After determining the number of conflicts or interferences, a report was made, which had to be exported from the same program quickly and automatically. This export can be done in different formats such as images, text, etc.

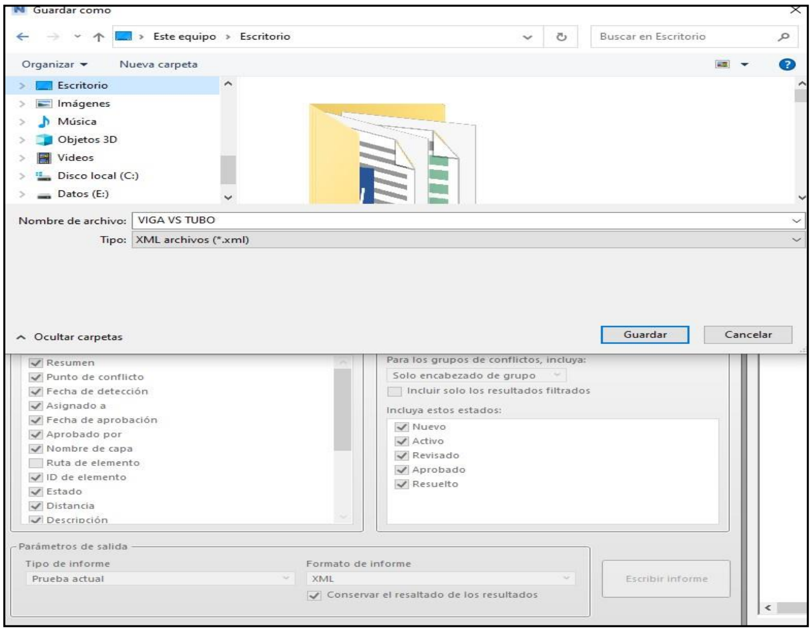


Figure 7. Steps to make the report, B-N°4 of project 1
Source: A.B.C. Arquitectos Ingenieros S.R.L. company.

- The following is the report of conflict reports for block 4.

								Elemento 1				Elemento 2			
Imagen	Nombre de conflicto	Estado	Distancia	Ubicación de rejilla	Descripción	Fecha de detección	Punto de conflicto	ID de elemento	Capa	Elemento Nombre	Elemento Tipo	ID de elemento	Capa	Elemento Nombre	Elemento Tipo
	Conflicto1	Nuevo	-0.108		Estático	2021/ 08:46	x:10.339, y:10.819, z:6.500	*ID de elemento*: 587454	03 Tercer Nivel NPT+6.50m	Hormigón, Moldeado in situ, gris	Sólido	*ID de elemento*: 726977	01 Primer Nivel NPT+0.00m	Tipos de tubería	Tuberías: Tipos de tubería: Tuberia-PVC SAP-Embone
	Conflicto 0	Nuevo	-0.026		Estático	2021 08:46	x:16.727, y:5.546, z:6.250	*ID de elemento*: 589848	03 Tercer Nivel NPT+6.50m	Hormigón, Moldeado in situ, gris	Sólido	*ID de elemento*: 719610	01 Primer Nivel NPT+0.00m	Tipos de tubería	Tuberías: Tipos de tubería: Tuberia-PVC SAP-Embone
	Conflicto13	Nuevo	-0.029		Estático	2021 08:46	x:16.729, y:-0.031, z:5.900	*ID de elemento*: 587466	03 Tercer Nivel NPT+6.50m	Hormigón, Moldeado in situ, gris	Sólido	*ID de elemento*: 725992	01 Primer Nivel NPT+0.00m	Tipos de tubería	Tuberías: Tipos de tubería: Tuberia-PVC SAP-Embone
	Conflicto12	Nuevo	-0.034		Estático	2021/ 08:46	x:4.263, y:2.379, z:5.900	*ID de elemento*: 587512	03 Tercer Nivel NPT+6.50m	M_Hormigón-Viga rectangular	Armazón estructural: M_Hormigón-Viga rectangular: V - 0.25X0.60 m	*ID de elemento*: 723778	01 Primer Nivel NPT+0.00m	Tipos de tubería	Tuberías: Tipos de tubería: Tuberia-PVC SAP-Embone
	Conflicto11	Nuevo	-0.043		Estático	2021, 08:46	x:16.778, y:5.464, z:5.900	*ID de elemento*: 587506	03 Tercer Nivel NPT+6.50m	M_Hormigón-Viga rectangular	Armazón estructural: M_Hormigón-Viga rectangular: V - 0.25X0.60 m	*ID de elemento*: 719610	01 Primer Nivel NPT+0.00m	Tipos de tubería	Tuberías: Tipos de tubería: Tuberia-PVC SAP-Embone
	Conflicto10	Nuevo	-0.054		Estático	2021, 08:46	x:16.775, y:5.567, z:6.500	*ID de elemento*: 588164	03 Tercer Nivel NPT+6.50m	Suelo	Suelos: Suelo: losa - 0.05	*ID de elemento*: 719610	01 Primer Nivel NPT+0.00m	Tipos de tubería	Tuberías: Tipos de tubería: Tuberia-PVC SAP-Embone

Figure 8.Conflict report, B-N°4 of project 1
Source: A.B.C. Arquitectos Ingenieros S.R.L. company.

- Finally, to resolve the interferences found, ice sessions were held, which were meetings between specialists to find solutions to these interferences, and once they were resolved, the information was updated in the ECD.

  Table 4 shows 5 figures: a) yields at the time of detecting interferences and b) quantity of interferences detected per specialty, elaborated for each block, exterior works, etc. These yields were established according to the person-hours spent per m^2 of the area worked, resulting in how long it took to check for incongruence per m^2 of the area and how many interferences were checked among the specialties.

  The considerations for identifying interferences in the Fatima project under the BIM approach were the same as for the Conadis project with the traditional system. The deliverable codes for Table 4 are as follows:

- Hh spent: Reflects the person-hours spent for that deliverable.

- M2 of verified roofed area: will reflect the square meter that belongs to the corresponding block.
- Fatima Project: FP; block 4: B4, etc.

Table 4

Data collection of the number of interferences detected between specialties and data collection of detection performance (BIM methodology - project 1).

No. of outlets	Deliverable Code	Date	(c) Review time (Hh employed)	(d) m2 of area verified roofed	(a) Detection number of interference detected	(b) Number of specialties revised (Und)	Number of interferences between specialties = (a) / (b)	Interference detection performance = c/d
1	PF-B4(total block revision)	22/01/2021	0.33	441.14	13	4	3.25	0.0008
2	PF-B8(total block revision)	22/01/2021	0.33	660.76	10	4	2.50	0.0005
3	PF-B10(total	22/01/20	0.3	561.	12	4	3.00	0.0006

	block revision)	21	3	69				
4	PF-EXT	22/01/2021	0.33	80.00	11	4	2.75	0.0042
5	PF-CISTERNA	22/01/2021	0.17	20.00	5	4	1.25	0.0083

Source: Own elaboration.

3.2. Process of elaboration of metrics

This section will describe the process of elaborating metrics executed in the company for projects 1 and n2 in the years 2019 and 2021 to describe and demonstrate that the BIM methodology is an excellent alternative in this process. First, the metrics were performed under different approaches: the traditional process and with BIM, the latter using Autodesk Revit software. By performing under these two approaches, it was possible to quantitatively determine the benefit expressed in the optimization of the performance of BIM vs. the traditional process, which will be explained in the results chapter. Next, the sequential steps taken into account for the extraction of measurements are described and delimited in the specialties of structures and architecture.

RESULTS

The results of the processed data are presented below:

Structural and architectural drawing process

The 13 data of the project's drawing-up times were processed with the traditional process and under the BIM approach in order to perform the descriptive analysis and interpret the results; use was made of the measures of central tendency, specifically the mean, to obtain these values presented in Table 7 and Figure 9; the IBM SPSS Statistics Visor software was used to calculate the data.

Table 7

Statistical data on timeframes for drawing up plans

	N	Minimum	Maximum	Media	Desv. Deviation
Traditional (project n°2)	13	76.1905	100	87.0236	7.7651

BIM (project n°1)	13	18.8889	55.5556	31.7369	10.4541
N valid (per list)	13				

Source: Own elaboration.

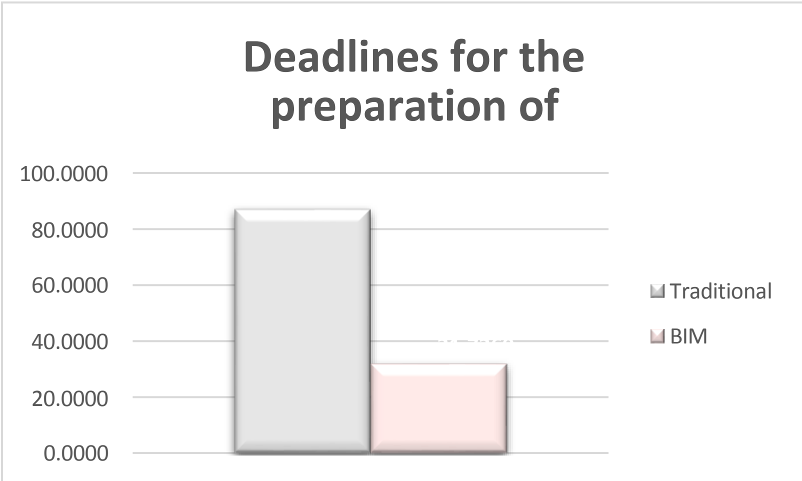


Figure 9.Histogram of time required to draw up plans (average)
Source: Own elaboration.

Table 7 and Figure 9 show the data for the average time.

The time required to draw up plans for the projects analyzed; the average time required for the traditional approach is 87.0236 times and 31.7369 times with BIM. In other words, the time required to draw up plans for the traditional approach is optimized with BIM by 64% or 55.2867 times less. In other words, it takes more person-hours to draw structural and architectural drawings with the traditional approach than with the BIM approach.

Interference detection and resolution process

The project's interference detection data has been processed with the traditional process and under the BIM approach to perform the descriptive analysis and interpret the results. In addition, use was made of the measures of central tendency, specifically the mean, to obtain these values presented in Table 8 and Figure 91. The IBM SPSS Statistics Visor software was used to calculate the data.

Table 8
Interference detection statistics

	N	Minimum	Maximum	Media	Desv. Deviation
		Number of interferences:			
Traditional (project n°2)	5	0.75	2.50	1.35	0.67546
BIM (project n°1)	5	1.25	3.25	2.55	0.77862
		Interference detection performance:			
Traditional (project n°2)	5	0.0071	0.0500	0.0257	0.01871
BIM (project n°1)	5	0.0005	0.0049	0.0029	0.00342

Source: Own source

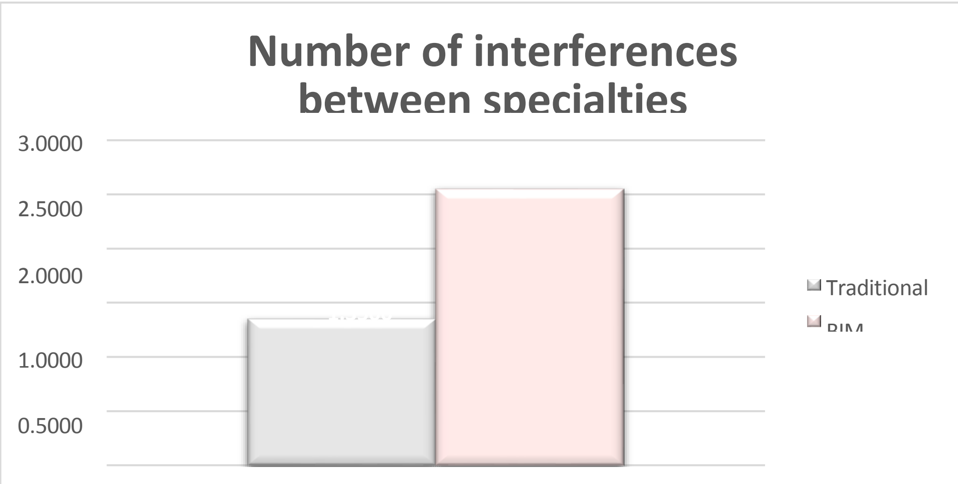


Figure 10: Histogram of number of interferences between specialties (average)
Source: Own elaboration

Table 8 and Figure 10 present the data of the average number of interference between specialties of the analyzed projects; these with the traditional approach reflect an average of 1.35 times and with BIM 2.55 times; that is to say that the amount of interference between specialties of the traditional project is optimized with BIM by 88% or increases by 1.20 times. In other words, a more significant amount of interference detection and resolution between specialties is more accurately determined under the BIM approach.

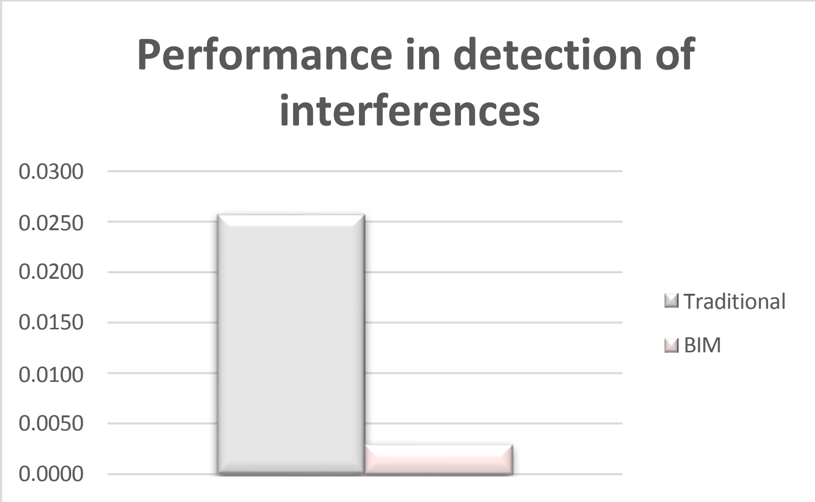


Figure 11: Histogram of timeframes for drawing up plans (average) Source: Own source

Table 8 and Figure 11 show the average data of the interference detection performance of the analyzed projects; these with the traditional approach reflect an average of 0.0257 times and with BIM 0.0029 times; that is to say that the interference detection performance of the traditional project is optimized with BIM by 112% or decreases by 0.0228 times. In other words, performing interference detection and resolution with the traditional approach requires more person-hours per m^2 than working under the BIM approach.

Process of elaboration of metrics

The 30 project performance data have been processed with the traditional process and under the BIM approach in order to perform the descriptive analysis and interpret the results; use was made of the measures of central tendency, specifically the mean, to obtain these values presented in Table 9 and Figure 12, for the calculation of the data the IBM SPSS Statistics Visor software was used.

Table 9

Statistical data on the performance of the metrados

	N	Minimum	Maximum	Media	Stand. Deviation
Traditional (project n°2)	30	0.0316	0.0200	0.0093	0.0043
BIM (project n°1)	30	0.0005	0.0049	0.0027	0.0015
N valid (per list)	30				

Source: Own elaboration.

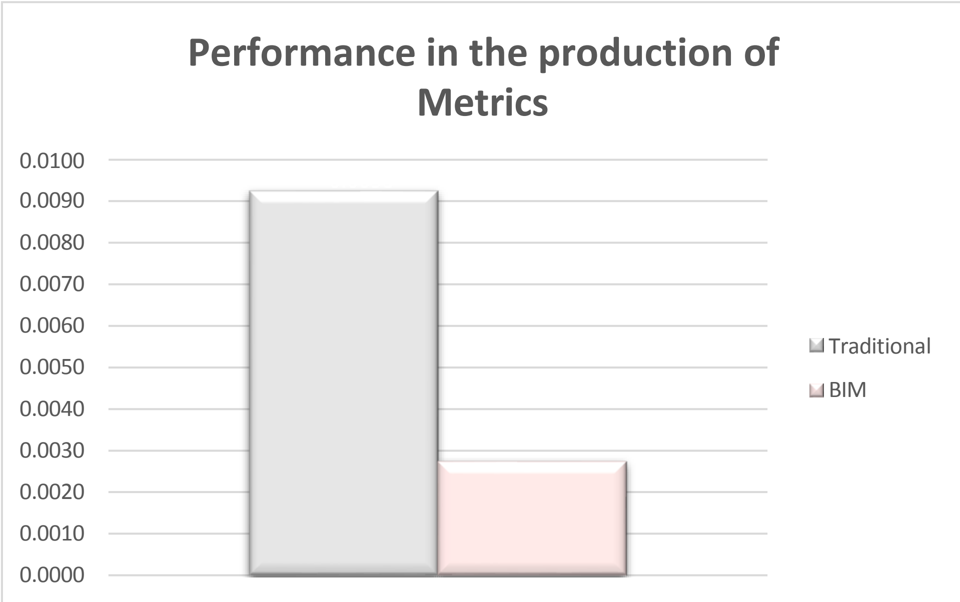


Figure 12. Histogram of metrics yields (average)
Source: Own elaboration.

Table 9 and Figure 12 present the data of the average yields of the metrics in the analyzed projects; the yields with the traditional approach reflect an average of 0.0093 times and with BIM 0.0027 times; that is to say that the yield of the metrics of the traditional project is optimized with BIM by 70% or decreases by 0.0065 times. In other words, the traditional approach requires more person-hours per m^2 than the BIM approach.

CONCLUSIONS AND RECOMMENDATIONS

- It was described and demonstrated that the BIM methodology optimizes education sector projects in an urban environment at the design stage, Lima 2021, thanks to the development of the specific objectives in this study.

  Sufficiency was based on the experience acquired in the ABC Arquitectos Ingenieros SRL company by comparing tasks or deliverables for both approaches and using descriptive data analysis.
- According to what has been described and demonstrated, the BIM methodology optimizes timeframes by 64% in preparing plans in the design stage of projects in the education sector in an urban environment. Furthermore, this is due to many factors such as the preparation of floor plans, cuts, elevations, details, etc. in the traditional process, which is done manually, independently and consecutively; that is, when there are modifications or corrections, the affected element or detail must be updated in each plan and this often demands much extra time and is not executed efficiently, because it depends on: a) the number of corrections, b) the magnitude of

the project and c) the experience of the professional. On the other hand, with the BIM methodology, there is a great advantage, which translates into a better presentation of definitive plans. Moreover, in the reduction of time and cost demands in subsequent modifications, thanks to the fact that there is a central virtual model, in other words, the action of updating the plans is expedited, the change is automatic, updating all the details generated for its presentation. On the other hand, under the traditional approach, the knowledge was acquired in the university stage in both design and drawing; however, it was not necessary to have experience or precise knowledge of the construction process of the building; but when developing plans under the BIM approach, the knowledge was necessary, since the modeling should be done as the building is executed, that is to say, the modeling is the virtual form of how the project will be executed.

- According to what has been described and demonstrated, the BIM methodology optimizes the detection and resolution of interferences by 88% and 112% in the design stage of projects in the education sector in an urban environment. The optimization is given both in the fast process of detecting interferences and in this efficiency. That is to say, the review is performed integrally, with fewer objections; it also benefits the workflow since it allows to generate a report. This goes to the Ice sessions for discussion and resolution, allowing the update in the common data environment, and hosting the model with the latest corrected version for all. In contrast, under the traditional process in the company under study, this action of detecting and resolving inferences was subject to the cognitive ability of the professional, and this was a function of the degree of experience and the time established for review, that is, the longer the time, the higher the quality of review between specialties, in the traditional approach, once the interferences were detected, it was up to each specialist to correct them independently, there being no meetings to resolve the drawbacks in the plans.
- According to what has been described and demonstrated, the BIM methodology optimizes performance by 70% in developing metrics in the design stage of projects in the education sector in an urban environment.

  BIM streamlines the processing of measurement extraction, so fewer person-hours are needed for this activity, and all this is because, in the modeling stage, the project was previously fed with the necessary characteristics and information required in the metrics stage. Although it is true that in Project 1, coarse metrics were developed at the client's request, at this stage, it was possible to develop sectorized metrics without problems and with ease, that is, quantification for each block; this would have taken a great deal of time under the traditional process, and possibly would have exceeded the deadline. On the other hand, the project under the BIM approach, in the face of modifications in the modeling, provided slack in time to the workflow because the updating of the modifications in the metrics occurred quickly and automatically. After all, what is modified is the central model, a model that is intertwined with the dynamic tables that are the metrics.

RECOMMENDATIONS

- As a general recommendation, it is important to have a clear idea of the objective of

  Modeling in BIM, that is, for what purpose such action is to be performed; it can be just for visualization, interference reporting or quantification of materials. By identifying the objective, a clear work path is established and time wasted on unnecessary modeling elements is avoided, thus saving person-hours.

- As a specific recommendation, for the elaboration of plans under the BIM methodology,

  The project's quality and the workflow's agility will depend on it. Therefore, the BIM project coordinator must establish these criteria to allow quick and adequate extraction of measurements in the metrics stage. It is also important to mention that the BIM methodology does not solve the problems but helps to manage the information. Finally, it is recommended that the modeling of each specialty originate in the same BIM program without using other formats such as .dwg.
- As a specific recommendation, the benefits of the BIM methodology must be considered, with the detection of interferences, in its two forms: through the models created in the Revit software and through the Naviswork program; in order to detect in advance all errors, which are always reflected in work, generating losses in cost and time; so that clash detective" or interference detection is essential to increase the profitability of a project.

- As a specific recommendation, for the development of metrics with BIM, it is important to have appropriately generated parameterized models with criteria to measure, that is, with the appropriate characteristics that each element should have, since the result of the measurements will depend on this. In addition, for these to be adequate, it will often be necessary to modify the model, adding relevant information to facilitate extraction. Likewise, the quality and speed of obtaining the measurement will depend on the knowledge of the categories that belong to each element to be measured and the parameters it needs.

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